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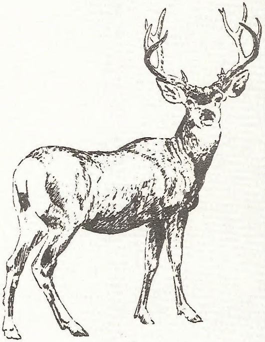

A FINAL REPORT

Research Branch
Arizona Game and Fish Department

Federal Aid in Wildlife Restoration
Project W-78-R

AUGUST, 1986

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Federal Aid in Wildlife Restoration Project W-78-R
Work Plan 2, Job 18
July 1, 1977 to June 30, 1985

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Abstract: During the 1970's there was a decline in the numbers of mule deer which summer on the Kaibab Plateau. The decline halted and reversed concurrently with a decrease in mountain lion (Felis concolor) numbers and the development of a long wet spell which generally improved deer food production. In addition to drought and lions there were unknowns, possibly coyotes (Canis latrans) and/or hunter crippling and poaching, which also contributed importantly to the high mortality rate of does in 1972-1976. None of these factors has been critical since 1979, as evidenced by low mortality of radio collared does and the pellet count index of an increasing deer herd. Numbers of cattle which share the deer food supply were greater before than during this study. Associations of female deer losses and mortality with annual fluctuations of weather, buffer species, and other environmental conditions appeared generally weak and complicated. Drought appropriate for these kinds of tests did not occur during the study.

INTRODUCTION

A decline in the number of mule deer summering on the Kaibab Plateau, evident about 1976, was thought to be due largely to non-hunting season mortality. This resulted in proposals to the Department to begin a predator control program. The major objective of the present study was part of an effort to determine causes of mortality not attributable to the reported hunter harvest, and thus provide a basis for a management decision on the predator control proposals.

A study coordinated with this one (Shaw 1980) estimated lion numbers and their deer kill rates during the early portion (1977-1980) of the deer observations reported here. This report compares results of another study which estimated deer mortality rates when the herd was declining (Barlow and and McCulloch 1984).

Radio tracking techniques for the primary objective of the present study also facilitated secondary objectives, one of which was to determine seasonal movements and habitat types used by deer. This will be described in another report.

The radio deer study also offered some additional deer herd characteristics to use with data collected for another study, Work Plan 2, Job 12, which relates parameters of the deer population with a 15-30 year history of weather and other environmental variables. The segment relating radio deer mortality to some of those factors is reported herein.

We have appended detailed descriptions and evaluations of some of the equipment and procedures adapted for this study.

We are grateful to Shikar Safari International for leasing to the Department the aircraft essential for monitoring the deer radios. For advice and equipment and personal service we are also indebted to the New Mexico Department of Game and Fish, the Utah Division of Wildlife Resources, Kaibab National Forest, Grand Canyon National Park, Bureau of Land Management, and many volunteers. Jay Barlow and Ron Smith made helpful comments on the manuscript.

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METHODS

Deer were equipped with mortality sensing radio collars made by Telonics, Inc. These transmitted a pulsing signal which accelerated when left stationary for some pre-set time, usually four hours although a few two-hour delay collars were also used. When heard via radio receiver (Telonics TR-2) this fast pulse was assumed to indicate a dead animal and a location was noted. A search for the carcass began usually within 24 hours.

The deer transmitters operating at frequencies of 148 to 149 mHz were usually monitored at three to five day intervals throughout the study. Locations of all functioning units were obtained at approximately three week intervals. All monitoring was done from a Piper Super Cub (PA-18). It was rigged with twin phased three-element Yagi antennas attached to the wing struts, and a directional H-antenna belly mounted on a rotary mast. This could be extended below wheel level while the plane was airborne.

A ground search for transmitters emitting fast pulse was done with a hand held H-antenna and the TR-2 receiver. When the carcass was found an assessment was made of the cause of mortality. Criteria for these judgments are listed in the Appendix. They were developed partly from our own experience but largely from reports of other observers (Cheatum 1949; Hornocker 1970; Ozoga and Harger 1966; Robinson 1952; Shaw 1983; Truett 1979; Wade and Bowns 1982; White 1973).

The sample of captured deer and the distribution of capture sites were intended to provide a radio collared sample representative of the Kaibab deer population. Since the number of radios available for use was limited, most units were placed on does. We hoped to have the radio equipped individuals dispersed as widely as possible among several thousand seasonally migratory deer on 1,200 square miles (3,108 km^2) of habitat. This study area includes 575 square miles (1,489 km^2) of coniferous forest summer and fall deer range on the Kaibab Plateau. This is adjoined by the habitat of transitional and winter seasons in woodland and cool desert shrub savannah at elevations below the forest. A detailed description of this habitat was done earlier (Rasmussen 1941).

From February 2, 1978 to July 21, 1982 radio collars were placed on 11 bucks and 77 does older than 12 months, and on 13 male and 14 female fawns 6-9 months old. These 115 deer were captured through a combination of box traps (Clover 1956), drive nets (Beasom et al. 1980), and rocket and cannon nets (Hawkins et al. 1968). The number of functioning transmitters in the field at

any time ranged from 26 to 78. In addition to the radio collars, a plastic tag 2-3/4 by 2-3/4 inches (7 x 7 cm) was attached to one ear of each deer.

There were two categories of attrition among the radio collared deer, so we distinguish "mortality" from "loss." The former represents confirmed deaths only, whereas loss refers to the sum of confirmed deaths plus radios which became silent due to unexplained causes. Thus the loss rate is the possible upper limit of a partly unknown rate of mortality. As explained below, we suspect that some of the radio silence was caused by factors other than death of deer, but there was no way to determine the true incidence of deaths among the deer with silent radios.

Each rate, mortality or loss, was calculated based on a radio-deer-day (RDD). It is assumed that Xi (the number of radio deer that began the ith day) and Yi (the number of radio deer that died or had radios become silent on the ith day) is known; and that each RDD is an independent trial of a binomial event, death or loss being one possibility and survival being the other. When a mortality was detected and verified on the ground, the date of death was usually estimated from the condition of the carcass. When inspection was delayed and the carcass evidence was not suitable for such estimate, date of death was placed midway between the last time the animal was monitored alive and the date when the mortality signal was heard. The date for an unexplained silent radio was simply that of its last recorded signal.

Average daily survival probability during a period of (n) days was estimated according to a method of Trent and Rongstad (1974: 462) thus:

$$Sd_i = (X_i - Y_i) / X_i = \text{daily survival rate for the } \underline{ith} \text{ day, and}$$

$$\bar{S}\bar{d} = \sum_{i=1}^{n}(X_i - Y_i) / \sum_{i=1}^{n}(X_i) = \text{weighted mean daily survival rate, and}$$

$\bar{S}\bar{d} = (X - Y) / X$, where X = RDD and Y = number of deaths or losses.

It was further assumed that the survival probability rate was constant over (n) days of a stated season, and the probability of survival over (n) consecutive days,

$$Sn = [(X - Y) / X]^n = (\bar{S}\bar{d})^n.$$

The average probability of mortality or loss over (n) days is simply the complement of the seasonal survival rate,

$$Mn = 1 - Sn.$$

Annual rates (Mn) of either mortality or loss were calculated for periods beginning July 1, the approximate peak of the fawn birth season and start of the deer life cycle. Seasonal rates were calculated to conform with expected or demonstrated sex and age differences in stress and hazard periods of the annual cycle.

Each season or other period is designated by the calendar year in which it ends. Month designations include the first and last day of the month

unless otherwise specified. Deer age classes indicate age at the start of the year or seasonal fraction of a year for which mortality and loss rates were calculated. We assume that females about 1 year of age have not conceived; that does about age 2 bear their first fawn; and that does age 3 years and older are multiparous.

Poisson confidence limits of survival and mortality rates were determined by the procedure of Trent and Rongstad (1974: 462) using tables of Fisher and Yates (1963: 65). Differences between rates were tested according to another method noted by Trent and Rongstad (1974: 463) using tables of cumulative binomial probabilities (Ann. Computation Lab. Harvard Univ. 1955).

There were highly variable periods of verified presence of individuals in the radio monitored group of deer. Animals were captured and collared at various dates, and deleted from the radio monitored group at irregular intervals by confirmed death or radio silence. The formula of Trent and Rongstad (1974: 462) makes allowance for seasonal clustering of deaths, and for those variable exposures to the possibility of death or radio silence during a stated period. A simple tally was done only to show the relative frequency of causes of death. With that exception all mortality and loss rates were temporally weighted to minimize the biases due to variation in the length of the monitoring period.

A mortality rate for the main (non-radio) doe population was calculated from age class abundance harvested by hunters during a period which preceded the present study (Barlow and McCulloch 1984). That earlier mortality rate included a fraction assigned to lions by assuming a stable lion population of 40 adults, which killed 32 deer per year not selective of deer age or sex (Shaw 1980: 10). The lion kill rate was applied to the 1976 herd estimate of 7,242 deer with fawns included. Annual estimates of the total adult deer population of the Kaibab Plateau were based on fecal pellet accumulation rates estimated on permanent sample plots, also previously described (Barlow and McCulloch 1984). The fawn fraction was added to that population on the basis of ratios of fawns to does from field classification counts.

The numbers of marked and unmarked deer seen by crews making field classification counts were recorded each year on summer range in October; on winter ranges in December-January; and by crews doing the pellet counts in September. Likelihood of poachers seeing marked deer was judged from the cumulative totals of deer sighted by those crews, and the cumulative totals of radio deer known to be present from about October 1 to December 1 each year.

Deer hunts during the present study were buck only in which hunter numbers were controlled by special permits. Hunt pressure (days afield) was estimated from responses to a mailed questionnaire to hunters. Carcass and antler data were collected at field checking stations where all successful hunters were required to bring their deer carcasses for inspection. Hunts through 1976 had been for any deer, also by controlled permit numbers.

Tests were made of associations of deer losses and mortality with environmental variables such as weather and indices of abundance of prey buffer species. Correlation coefficients were calculated for the paired variables.

Water year (October-September) precipitation was recorded via storage gauges at nine stations in winter-intermediate seasonal habitat of deer at elevations of 1,722 m to 1981 m (5,650 ft. to 6,500 ft.) on east, west, and north vicinities of the Kaibab Plateau. Winter temperatures were provided by thermograph at a west side station at 1,975 m (6,480 ft.) and an east side station at 1,890 m (6,200 ft.). Days of snow cover $\geq$ 2.5 cm were determined by direct observation at elevation 1,975 m (6,480 ft.) on the west side habitat.

Catches along snap trap lines provided indices to the annual fluctuation of rodent abundance on two sites in winter deer habitat. Both were in areas where pinyon (*Pinus edulis*) and juniper (*Juniperus osteosperma*) tree cover had been removed by bulldozers in 1954-1956. Each line had 100 traps spaced 10 m apart and baited with peanut butter and oatmeal. Victor rat traps were used with trigger pans extended to 5 cm by 5 cm (2 in. by 2 in.) to take small as well as large rodents. One line became unusable in 1982 after sagebrush (*Artemisia tridentata*) and cliffrose (*Cowania mexicana*) shrub cover was destroyed to improve grass for cattle.

Indices of abundance of jackrabbits (*Lepus californicus*) and cottontails (*Sylvilagus audubonii*) were calculated from roadside counts on fixed routes. One was in east side winter deer range (29.5 miles, 47.8 km) and the other, in west winter deer range (27.7 miles, 44.9 km). Both routes were run on five consecutive nights in August as described in the Appendix.

An index of annual fluctuations in botanical quality of winter deer diets was obtained for each of two sites of winter deer concentration. At the end of winter, one pellet was collected from each of 50 deer pellet groups as encountered by the observer on a meandering route of 1-3 km (0.5-1.5 mi). Composition of the 50-pellet sample from each site each year was determined by the Composition Analysis Laboratory, Range Science Department, Colorado State University.

Indices of annual fluctuations of coyote abundance were attempted with a scent station technique (Linhart and Knowlton 1975). One of the 23.7 km (14.7 mile) routes was in west side winter deer range. Another was in deer summer range and fawning areas on the Kaibab Plateau, and the third was in and adjacent to (within 1 km, 0.5 mile) deer winter range east of the Plateau.

RESULTS AND DISCUSSION

History has silenced the question of the need for a predator control project to halt the deer decline of the 1970's. Comparison of the deer telemetry data with evidence from the preceding period (Barlow and McCulloch 1984) shows that doe mortality rates decreased (Fig. 1). The pellet counts showed a great increase in total herd size (Fig. 2). These improvements occurred without any management actually aimed at reducing the number of predators.

There was, however, an important change in numbers of at least one of the chief predators of deer. The Kaibab lion population declined during the period 1977-1980 (Shaw 1980: 10). The deer mortality rate differences among years (1979-1981, July-June) were not statistically significant (Table 1).

The samples of lion killed deer and the estimated mortality rates were too small to allow detection of any annual trend during the period 1979-1981. For the complete five-year period 1979-1983, the average annual rate of lion caused mortality of radio does was appreciably lower than the estimated lion kill rate of the main doe herd during the deer decline era of 1972-1976 (Fig. 1).

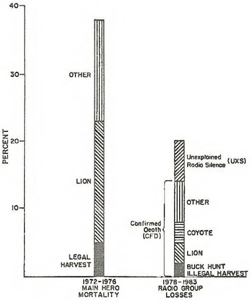

Fig. 1. Annual mortality and loss rates of does older than 12 months.

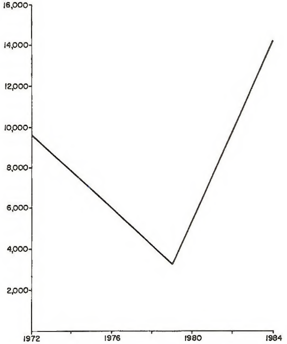

Fig. 2. Gross change in herd size on summer range 1972-1984.

Table 1. Annual (July-June) rates of lion caused deaths of does at least one year old.

Years Ending	Mortality	Survival[a]	Radio 95% CI	Deer Days	Deaths
1978	--	--	--	--	--
1979	0.073	0.927[a]	0.760-0.991	9,599	2
1980	0.044	0.956[a]	0.848-0.995	16,036	2
1981	0.018	0.982[a]	0.902-0.999	19,690	1
1982	0.022	0.978[a]	0.884-0.999	16,425	1
1983	0.000	1.000[a]	0.912-1.000	14,661	0
Pooled 5 years	0.028	0.972	0.940-0.990	76,411	6

[a]Probabilities (rates) within a column and followed by same letter are not significantly different ($P > 0.10$).

Effect of Coyotes. It is not possible to compare the coyote caused death rates of does during the periods, 1972-1976 vs. 1979-1983 since there were no techniques for assessing the coyote caused rate prior to the deer telemetry study. However, some factors in addition to lions contributed importantly to the non-hunter-harvest fraction of doe mortality during the deer decline; we cannot confirm or deny coyotes in the "other" category of the graph (Fig. 1).

The hypothesis that coyotes can significantly affect deer mortality is implied by the observation that, under conditions of adverse weather and poor forage, coyote control has been associated with spectacular but unsustained increases in the survival of yearling does, during a longer period of generally low levels of deer production on this area (McCulloch, S.W. Nat. in press). However, during the present deer telemetry study there were no significant differences in coyote caused death rates among years when weather and forage conditions were more favorable (Tables 2, 3).

Table 2. Annual (July-June) rates of coyote implicated deaths of females at least one year old.

Years Ending	Mortality	Survival[a]	95% CI	Radio Deer Days	Deaths
1978	--	--	--	--	--
1979	0.000	1.000[a]	0.869-1.000	9,599	0
1980	0.045	0.955[a]	0.848-0.995	16,036	2
1981	0.072	0.928[a]	0.827-0.980	19,690	4
1982	0.000	1.000[a]	0.921-1.000	16,425	0
1983	0.049	0.951[a]	0.835-0.994	14,661	2
Pooled 5 years	0.038	0.962	0.927-0.984	76,411	8

[a]Probabilities (rates) within a column and followed by same letter are not significantly different ($P > 0.09$).

Mountain Lions. Lions appeared to select fawns among the radio deer group. The lion caused mortality rate of second semester fawns was significantly greater than that for does older than 30 months during the December-June seasons of 1978-1981 ($P < 0.05$). Coyotes on the other hand appeared not to select between does and large fawns on winter range. There were no significant differences in the coyote implicated mortality rates of second semester fawns vs. does older than 30 months during December-June of 1978-1981 ($P > 0.10$).

Table 3. Fawning season (May-September) rates of coyote implicated deaths of does of breeding age (greater than 22 months).

Years Ending	Mortality	Survival[a]	95% CI	Radio Deer Days	Deaths
1978	0.039	0.961[a]	0.801-0.999	3,839	1
1979	0.000	1.000[a]	0.896-1.000	5,147	0
1980	0.040	0.960[a]	0.864-0.995	7,543	2
1981	0.040	0.960[a]	0.862-0.995	7,450	2
1982	0.000	1.000[a]	0.919-1.000	6,713	0
1983	0.000	1.000[a]	0.901-1.000	5,417	0
Pooled 6 years	0.021	0.979	0.952-0.993	36,109	5

[a]Probabilities (rates) within a column and followed by same letter are not significantly different ($P > 0.10$).

Illegal Kill. The annual rate of illegal kill of radio does during the buck only hunting seasons was lower than either of the rates of deaths caused by lions or coyotes (Fig. 1). The combined rate of hunt associated mortalities and losses for radio does during buck hunts was about 3% and for out of season poaching less than 1%. The greatest mortality that could be speculatively attributed to poaching was 10%, the sum of rates of confirmed poaching and deaths with no clues plus unexplained silent radios. The deer telemetry data is not retroactive, of course, and the "other" portion of the 1972-1976 graph remains unexplained (Fig. 1). Crippling loss, legal or illegal, could have been important during the any deer hunts.

We suspect that radio silence (Fig. 1) was often due to radio failure or other technical problems and not death. The silent radios sometimes gave weak or erratic signals for days or weeks before they finally became silent. The failure of two radios were known. Bucks wearing them were seen alive 6 and 51 months after the transmitters went silent.

Although the unexplained radio silences could not be attributed to death, their possible effect on mortality rates in aggregate ranged from 0 to 11 percent among the rates for different groups of deer; that is, when unexplained silent radio rates were added to confirmed mortality rates (Table 4). We believe that something other than poaching was responsible for much of the unexplained radio silence. The evidence of poaching in relation to this is not conclusive but may be interesting and is presented in the Appendix. Since poachers conceivably could avoid marked deer, that mortality factor remained elusive from study.

Table 4. Among years variations in rates of death and losses by sex, age, season.

	1978	1979	1980	1981	1982	1983	Pooled Years
Annual (Jul.-Jun.) rates:							
Females age > 12 mo. mortality	.--	.15	.10	.23	.09	.14	.14
loss	.--	.17	.10	.35	.18	.19	.21
Males age > 12 mo. mortality	.--	.71	.21	.41	.11	.25	.27
loss	.--	.75	.21	.41	.22	.25	.32
Trophy bucks age > 36 mo. mort.	.--	1.00	.--	1.00	.25	.49	.57
loss	.--	1.00	.11	1.00	.60	.49	.68
Fawn second semester (Dec.-Jun.):							
Male and female age 5-12 mo.							
mortality	.00	.21	.20	.25	.--	.--	.25
loss	.00	.21	.35	.32	.--	.--	.34
Winter (post hunt-Apr.) rates:							
Females age 5-10 mo. mortality	.00	.74	.00	.29	.--	.--	.26
loss	.00	.74	.00	.29	.--	.--	.26
Females age 17-22 mo. mortality	.44	.00	.20	.00	.32	.--	.17
loss	.44	.00	.20	.00	.32	.--	.17
Females age > 29 mo. mortality	.00	.00	.02	.02	.02	.07	.02
loss	.00	.00	.02	.14	.02	.09	.04
Fawning season (May-Sep.) rates:							
Females age 10-15 mo. mortality	.00	.00	.--	.21	.--	.--	.09
(Table 7) loss	.00	.00	.--	.21	.--	.--	.09
Primiparas age 22-27 mo. mort.	.00	.00	.00	.00	.00	.--	.00
(Table 8) loss	.00	.00	.00	.23	.39	.--	.13
Multiparas age > 34 mo. mort.	.12	.03	.10	.10	.00	.06	.07
(Table 6) loss	.12	.03	.14	.18	.00	.11	.10
Males age > 22 mo. mortality	.00	.00	.00	.00	.00	.00	.00
loss	.00	.00	.00	.00	.00	.00	.00
Trophy bucks age > 40 mo. mort.	.00	.00	.00	.00	.00	.00	.00
loss	.00	.00	.00	.00	.00	.00	.00

Table 5. Yearly variations of some environmental indices and deer herd characteristics.

	1977	1978	1979	1980	1981	1982	1983
Precip. 9 stations winter range, inches:							
Water year Oct-Sep	7.49	14.05	20.86	19.26	15.49	18.19	20.34
Oct-May season	3.50	12.04	19.25	15.05	8.69	10.69	12.21
Jun-Aug season	3.45	0.83	1.52	3.14	5.33	6.21	5.61
Snow cover W Dec-Mch, days	19	21	116	22	14	61	45
Mean temp. W Dec-Mch, daily	38.0	39.2	31.4	36.8	40.0	35.8	--
Rabbits per road mile:							
Jackrabbits W Aug, high	--	--	3.94	1.37	1.60	0.65	--
Jackrabbits E Aug, high	--	--	0.14	0.30	0.37	0.31	--
Cottontails W Aug, high	--	--	0.25	0.07	0.11	0.11	--
Cottontails E Aug, high	--	--	0.10	0.03	0.03	0.10	--
Rodents per 300 trap nights:							
W Aug-Nov	30	136	20	21	114	--	--
E Aug-Nov	49	199	35	96	124	39	--
Scent station visitation index:							
Coyotes W Sep-Oct	80	245	179	65	55	--	--
Coyotes E Sep-Oct	--	25	45	105	30	--	--
Coyotes summer range Sep-Oct	--	138	60	30	--	--	--
Winter deer diet west (Little Spring):							
Sagebrush %	22	56	16	84	42	--	--
Cliffrose %	47	39	78	10	55	--	--
Grasses %	11	3	1	5	1	--	--
Pinyon %	0	0	0	0	0	--	--
Winter deer diet east (Kane Trail):							
Sagebrush %	36	49	80	78	46	--	--
Cliffrose %	3	7	6	4	28	--	--
Grasses %	6	1	1	3	7	--	--
Pinyon %	15	33	8	7	6	--	--
Buck hunter days (from Table 4)	6,419	5,935	5,290	6,610	9,224	14,591	14,399
Yearling buck antler points/M	407	421	411	433	450	438	438
Yearling buck carcass lbs.	96	98	101	106	108	110	110

Table 6. Fawning season (May-September) loss and mortality of multiparous does (age greater than 34 months).

	Confirmed Deaths plus Unexplained Silences					Confirmed Deaths Only			
Year	Loss	Survival[a,b]	95% CI	Losses	Radio Deer Days	Mortality	Survival[a]	95% CI	Deaths
1978	0.122	0.878ab	0.684-0.974	3	3,533	0.122	0.878ab	0.684-0.974	3
1979	0.033	0.967a	0.830-0.999	1	4,565	0.000	1.000ab	0.884-1.000	0
1980	0.140	0.860ab	0.733-0.941	7	7,115	0.102	0.898ab	0.778-0.966	5
1981	0.182	0.818b	0.683-0.912	9	6,869	0.105	0.895b	0.771-0.965	5
1982	0.000	1.000a	0.916-1.000	0	6,407	0.000	1.000a	0.916-1.000	0
1983	0.107	0.893ab	0.745-0.970	4	5,417	0.055	0.945ab	0.815-0.993	2
Pooled 6 years	0.103	0.897	0.886-0.908	24	33,906	0.066	0.934	0.925-0.944	15

[a] Probabilities (rates) within a column and followed by same letter are not signficantly different ($P > 0.05$).

Climatic Factors. With all seasons and age classes of does pooled (Table 4) only 1981 had a loss rate higher than any other year ($P < 0.05$). The indices of environmental factors in 1981, however, were such as to favor low losses. There was an unusually warm winter with minimal snow cover, above average precipitation, low indices of coyote abundance, and high indices of rodents, cliffrose consumption, and deer physical condition (Table 5). The lumping of doe age classes and seasons obscured some factors associated with the puzzling high rate of loss in 1981. Stratification of the data showed that the high loss that year was chiefly among the multiparous does and during late gestation, birth, and lactation (Table 6). For that group of mature does the stratification revealed that the mortality rate also was higher in summer 1981 than in summer 1982, but not different from the rate of other summers. Younger female losses in the fawning season of 1981 were no higher than in other years (Tables 7, 8). The higher mortality of mature does in summer 1981 was due to a combination of factors. None was outstanding as judged by a simple tally of death causes: 3 other and 2 coyote. We did not calculate rates by causes in this case.

There were seasonal differences in loss rates of female age classes (Tables 4, 9). In winter, fawns had higher loss rates (December-April) than multiparas, so did yearlings. The older does had higher loss rates in summer (May-September) than in winter (December-April). These observations conform with the conventional view that the annual stress period of deer (Robinette et al. 1957; Klein and Olson 1960) varies with age.

Table 7. Fawning season (May-September) mortality of non-bred females (age 10-15 months)[a].

Years Ending	Mortality	Survival[b]	95% CI	Radio Deer Days	Deaths
1978	0.000	1.000	0.156-1.000	306	0
1979	0.000	1.000	0.396-1.000	612	0
1980	--	--	-- --	--	
1981	0.211	0.789	0.266-0.994	646	1
Pooled 3 years	0.093	0.907	0.579-0.998	1,564	1

[a]There were no unexplained silent radios in this group.
[b]Survival rate differences among years are not significant ($P > 0.10$).

We found no geographic difference in the non-hunt ("natural") mortality of females. The east-west difference was not significant in winter mortality rates of subadult females (Table 10). Neither were the differences significant in the fawning season loss and mortality of breeding does which wintered separately, east and west (Table 11). As noted above, younger females were the class more susceptible to death on winter range, whereas mature does died mostly on summer range where east and west winter groups mingled. From the earlier study, 1972 - 1976, we had theorized that any-deer hunt mortality might have been lower and non-hunt mortality higher among east wintering does, even though total annual mortality from all causes appeared equal in both geographic groups (Barlow and McCulloch 1984: 1810).

Table 8. Fawning season (May-September) loss of primiparous does (age 22-27 months)[a].

Years Ending	Loss	Survival[b]	95% C.I.	Radio Deer Days	Losses
1978	0.000	1.000	0.156-1.000	306	0
1979	0.000	1.000	0.156-1.000	306	0
1980	0.000	1.000	0.396-1.000	612	0
1981	0.192	0.808	0.304-0.995	718	1
1982	0.367	0.631	0.076-0.988	333	1
1983	--	--	-- --	--	
Pooled 5 years	0.126	0.874	0.615-0.984	2,275	2

[a]There were no confirmed deaths in this group.

[b]Survival rate differences among years are not significant ($P > 0.10$).

Table 9. Age and season differences in loss rates of females 1978 - 1983.

Season	Age Months	Rate Mean of Years
July - November	0-05	not observed
December - April	5-10	0.33[ab]
May - September	10-15	0.09
October pre-hunt	16	0.00
November hunt	17	0.00
December - April	17-22	0.22[b]
May - September	22-27	0.13
October pre-hunt	28	0.00
November hunt	29+	0.04
December - April	29+	0.04[ab]
May - September	34+	0.10[b]

[a,b]Means with the same letter are <u>different</u> $P < 0.05$). Each test was confined to the series of years of data available for both classes; fawn and yearling records were lacking after 1981 and thus were not compared with 1982 and 1983 data which were available for older females.

Table 10. Geographic difference in winter (December-April) mortality of subadult females (age 5-22 months)[a].

	Mortality	Survival[b]	95% C.I.	Radio Deer Days	Deaths
Deer wintered east	0.166	0.834	0.364-0.995	835	1
Deer wintered west	0.254	0.746	0.471-0.923	2,061	4

[a]There were no unexplained silent radios in this group. It excludes animals of the fraction of winter at the start of this study, March-April 1978, when there were no radio collared deer on the east side.
[b]The difference between areas is not significant ($P > 0.10$).

Precipitation (Table 5) was not correlated with mortality rates of either the pooled or the stratified age classes of females. Loss rates of yearlings and second semester fawns did not correlate with winter severity indexes, but this is inconclusive; there were no radio fawns and yearlings available to monitor in some years of the study. The pooled (greater than 12 months) age class had loss rates that correlated with snow cover and temperature indices of winter of the preceding year, but not with indices of the current winter (Tables 5, 12). Correlation with this mixture of ages and stress seasons seems to fit no causal hypothesis. Weather during the present study was not sufficiently variable to permit comparisons of mortality with maximum adverse conditions such as prolonged drought, or even a short one following a cold, snowy winter. The study period was in fact the wettest in 60 years. Concurrent with such favorable conditions for forage growth were progressive annual reductions in cattle numbers on most of the deer habitat. These are examined in a separate report for Work Plan 2, Job 12 (McCulloch, unpubl. ms.).

Effects of Rabbits, Rodents. The association of deer losses with indices to buffer prey species abundance appeared to be weak and anything but simple. The jackrabbit index did not correlate with any age or seasonal class of the female deer losses of either the current year or the one following the jackrabbit condition (Tables 5, 12).

Multiparous doe losses to all causes on fawning grounds (summer range) correlated negatively with rodent abundance that occurred on west winter range six to 12 months earlier. Losses of this doe group correlated negatively with rodent abundance that occurred on west winter range six to 12 months earlier. Losses of this doe group correlated positively with cottontail abundance during the same summer on east winter range (Tables 5, 12).

Winter to spring fawn losses correlated with the fall rodent indices immediately preceding the winter on both east and west sides (Tables 5, 12). This could either support or contradict the buffer theory, depending on whether or not the rodent populations declined severely during the winter.

Table 11. Geographic differences in fawning season (May-September) loss and mortality of multiparous does (age greater than 34 months), 1979-1983[a].

	Confirmed Deaths plus Unexplained Silences					Confirmed Deaths Only			
Area	Loss[b]	Survival[b]	95% CI	Losses	Radio Deer Days	Mortality	Survival	95% CI	Deaths
Deer wintered east	0.125	0.875	0.768-0.944	8	9,137	0.080	0.920	0.822-0.973	5
Deer wintered west	0.089	0.911	0.895-0.924	13	21,236	0.049	0.951	0.901-0.980	7

[a]Comparison excludes 1978 when there were no radio collared deer representing the east side.

[b]Probabilities (rates) within a column are not significantly different (P > 0.10).

Table 12. Loss and mortality rates of female deer associated with environmental indexes[a].

Paired Variables	r	P	df
Annual (Jul-Jun) loss rates of all females age greater than 1 year vs.:			
Days snow cover Dec-Mch of preceding calendar year	0.908	$\leq$ 0.05	3
Daily mean temperature Dec-Mch of preceding calendar year	0.891	$\leq$ 0.05	3
Sagebrush % diet, West, Dec-Mch of preceding calendar year	0.939	$\leq$ 0.10	2
Dec-Apr loss rates of female fawns age 6-10 mo. vs.:			
Rodents, west, in Aug-Nov of preceding calendar year	0.904	$\leq$ 0.10	2
Rodents, east, in Aug-Nov of preceding calendar year	0.996	$\leq$ 0.01	2
Sagebrush % diet, west, Dec-Mch of current calendar year[b]	-0.907	$\leq$ 0.10	2
Dec-Apr loss rates of yearling females age 17-22 mo. vs.: All indexes	ns	> 0.10	1-3
May-Sep loss rates of multiparas age greater than 34 mo. vs.:			
Days snow cover Dec-Mch of current calendar year	-0.796	$\leq$ 0.10	4
Cottontails, east in Aug of current calendar year	0.972	$\leq$ 0.05	2
Rodents, west, in Aug-Nov of preceding calendar year	-0.912	$\leq$ 0.05	3
Coyotes on summer range in Sep-Oct of preceding calendar year	0.999	$\leq$ 0.01	1
May-Sep rates of coyote implicated mortality of all does of breeding age greater than 22 months vs.:			
Current year cottontails east	-0.999	$\leq$ 0.01	2
Current year rodents east	0.8230	$\leq$ 0.10	3
Preceding year rodents west	-0.9889	$\leq$ 0.01	3

[a]Total tested: 139 paired variables.

As judged by the correlation tests, the coyote implicated mortality of does of breeding age (greater than 22 months) was low during fawning seasons when rodents had been abundant on winter ranges the previous fall (Tables 3, 12). The rate was also low when cottontails were abundant on east winter range during the current summer. As in the several cases of female deer losses the coyote implicated mortalities of breeding does did not correlate with jackrabbit indices.

We doubt that cause and effect were indicated by the correlation of coyote abundance on summer range with the summer losses of multiparous does the following year (Tables 3, 12). The coyote indices were ambiguous:high on the east side and low on the west side in one year, and vice versa the next. The scent station technique is not suited for localized annual indices as attempted in this study (Roughton and Sweeny 1982: 218).

For does the numerical list of causes of mortality (Table 13) has meaning chiefly in context with the mortality rates (Tables 1-4, 6-10, 14). Rates are also necessary to interpret the tally of causes for bucks, but the list of causes is much simpler.

Table 13. Tallies of confirmed deaths of deer and unexplained silence of radios (February 1978 - June 1983). [a]

	Deer Age >12 months				Fawns, Male and Female Age 6-12 Months	
	Bucks		Does			
Cause	No.	%	No.	%	No.	%
Lion	0	0	7	20.6	2	40.0
Coyote certain	1	11.1	1	2.9	1	20.0
Coyote probable	0	0	3	8.8	0	0
Unknown, coyote possible	0	0	4	11.8	1	20.0
Unknown, no clues	0	0	7	20.6	0	0
Unknown, poor condition	0	0	1	2.9	1	20.0
Unknown, not predators	0	0	3	8.8	0	0
Legal harvest	7	77.8	0	0	0	0
Hunt season cripple/illegal	1	11.1	6	17.7	0	0
Non-hunt season illegal	0	0	1	2.9	0	0
Accident	0	0	1	2.9	0	0
Total confirmed deaths	9	100.0	34	100.0	5	100.0
Total unexplained silences	2	--	17	--	2	--

[a]These are not exposure weighted rates of mortality and loss.

Effect of Hunting. Hunting was the only important mortality factor for radio bucks (Tables 4, 14). Larger, older bucks had much higher mortality rates than yearlings, thus confirming earlier evidence of hunter selection (Barlow and McCulloch 1984). That bias had precluded estimates of mortality of yearling bucks prior to the radio deer study.

Table 14. Rates of mortality and loss during buck only hunting seasons.

	1978	1979	1980	1981	1982	1983	Av	r[a]	P
Females age greater than 16 months:									
Illegal mortality	0.04	0.02	0.04	0.02	0.02	0	0.02	-00.707	>0.10
Loss	.04	.02	.04	.02	.02	0.07	.03	0.313	>0.10
Males age greater than 16 months:									
Harvest mortality	.71	.20	.28	0	.25	.10	.26	-0.422	>0.10
Cripple mortality	0	0	0	.11	0	0	.02	-0.014	>0.10
Loss	.71	.20	.28	.11	.25	.10	.28	-0.462	>0.10
Yrl males age 16-17 months:									
Harvest mortality	.61	.35	0	0	--	--	.24	-0.665	>0.10
Cripple	0	0	0	0	--	--	.00	--	--
Loss	.61	.35	0	0	--	--	.24	-0.665	>0.10
Trophy bucks age greater than 40 months:									
Harvest mortality	1.00	--	1.00	0	.49	.18	.53	-0.631	>0.10
Cripple	0	--	0	.25	0	0	.05	-0.125	>0.10
Loss	1.00	--	1.00	.25	.49	.18	.58	-.767	>0.10
Hunter days	5,935	5,290	6,610	9,224	14,591	14,399	--	--	--
Permits authorized	1,800	1,400	1,700	2,500	3,800	4,000	--	--	--
Herd location, seasonal range	Wntr	Sumr	Sumr	Sumr	Sumr	Both	--	--	--

[a]Correlation coefficient (r) for hunter days _vs._ deaths, losses, and probability (P) of correlation.

The pooled age class rates (greater than 12 months, greater than 16 months) for radio bucks probably do not represent the non-radio buck herd (Tables 4, 14). Inference from the radio group to the main buck herd would be confused because there were no radio collared yearlings during the heavy hunt years of 1982 and 1983; productivity was unusually high and yearlings were unusually available to hunters (unpubl. data); there were more hunts occurring on summer range than on winter range, and hunters select against or avoid yearlings, especially on winter range.

Hunt mortality appeared to increase since 1979 or perhaps earlier for bucks over 40 months old. There was some overlap between the buck data of the two studies; i.e. 1978-1983 and 1972-1979 (Barlow and McCulloch 1984). Nevertheless, we believe that the comparison indicates a large rise in the hunter kill rate of the "trophy" age class since the end of any deer hunts in 1976. The earlier annual mortality rate had been only 0.145 due to reported harvest of these bucks (Barlow and McCulloch 1984). Hunt vulnerability of the older radio bucks on winter range appeared greater than on summer range (Table 14). Cumulative binomial probability did and Poisson distribution did not indicate significance ($P < 0.05$) for this difference. It did, however, reflect the preference for trophy age bucks among hunters who request late hunt dates.

Yearling radio bucks had only a modest rate of loss to hunting during 1978-1981. With due allowance for the bias resulting from hunter selection and differences in buck behavior among age classes in those seasons, we judge that recruitment was unusually high; yearlings were unusually abundant. At the same time hunt permit numbers and hunter effort were much lower than in 1982 and 1983 (Table 14). We believe that recruitment of yearlings continued at high levels during the last two years of the radio deer study, but there were no radio collared yearlings with which to evaluate effects of hunting on that age group.

Neither the buck nor doe cripple/illegal loss was correlated with buck only hunt pressure (Table 14). For radio bucks the out of season rate of illegal kill (poaching) was zero. The low likelihood of a poacher sighting a marked buck is discussed in the Appendix.

SUMMARY

Doe mortality declined and the Kaibab deer population increased without a predator control program. The reversals in those two characteristics of the deer population were concurrent with major changes in the deer environment. They were a decrease in the lion population, onset of a series of wet years with abundant forage growth, and decreased cattle numbers.

The lion caused rate of doe mortality dropped drastically between the two study periods of 1972-1976 and 1978-1983, but lion kill alone was not enough to explain the high death rate of deer during the first period. The deer herd decline, which was observed 1972-1979 and possibly began earlier, was due to one or more major but unknown factors combined with the lion kills.

Although a radio-telemetry study in the early 1970's might have identified those unknowns, retroactive speculation can not separate the deer

death rates caused by archery and firearms hunt crippling, coyotes, out-of-season poaching, and other influences prior to 1978.

The confirmed and suspected mortality rate caused by coyotes was very low during the radio deer study period, 1978-1983.

The crippling rate of does as well as that of bucks has been very low during the buck-only firearms hunts evaluated after 1977.

Confirmed out-of-season poaching mortality rates have been even lower than the hunt crippling rates among radio-collared deer, 1978-1983.

The highest possible poaching loss, represented by confirmed poaching plus unexplained silent radios plus deaths with no clues, did not exceed 10% for does age 12 months and older.

Mortality was clustered seasonally and was different for different age classes of deer. Does of breeding age died mostly in summer; weaned fawns and yearling females died mostly in winter.

The firearms buck hunt, including crippling and reported harvest, was the only mortality factor for trophy age (3 years and older) bucks, 1978-1983. Total annual mortality of that mature buck class changed only slightly since 1972-1976, but the portion of that rate due to hunting had increased greatly as of 1983.

The hunt mortality rate for yearling bucks was low during 1978-1981, but we theorize that the rate may have gone up during the heavier hunts which occurred after 1981.

Two methods have been demonstrated for estimating mortality of Kaibab deer. One (composite harvest records) is economical to use and the other (radio telemetry) is thorough for evaluating various causes of deer deaths. They are special study techniques. Neither is feasible for routine annual assessments of herd status comparable with those of the hunter checking station, pellet counts, and field classification counts of deer by ground crews.

RECOMMENDATIONS

The ecosystem which includes the Kaibab deer herd is dynamic. Its components fluctuate obviously in magnitude and presumably in their effects on each other. There may have been times when coyotes had important direct effects on deer mortality. Under other conditions, as during the radio deer study, the effects of coyotes were minimal. Intelligent application of coyote control as a deer production technique requires ability to forecast conditions which will cause or allow coyotes to have a critical effect. The necessary understanding for such predictions is not well developed. In the meantime blind attempts at coyote control to enhance deer production are likely to be either superfluous or counter-productive. As an example of the former we would cite the recent period, 1979-1982, and of the latter, the 1080 poison campaigns of the 1950's (McCulloch in press).

Management of the Kaibab lion population by sport hunting seemed a promising technique as judged by the events of 1978-1980, when lion numbers went down and deer numbers went up. In this case also, reliable predictive knowledge is lacking. The effects of weather and livestock reductions can not be separated from the effect of the lion decline. Long term weather forecasts are not feasible, and neither are predictions of lion population response to sport hunting, although population modeling has been suggested as possibly helpful (Shaw 1980: 12).

Rather than attempt predator management in the near future, we could do more to benefit deer hunters by improving current techniques of managing this deer herd; i.e. to manage more closely. This requires prompt and precise changes in hunt permit numbers in response to annual fluctuations in herd size and sex-age composition. The perennial inventory techniques essential for such decisions need refinement and data on file should be examined for guidance.

Continuous review of policy and planning documents is necessary to forestall proposed vegetation changes which could degrade deer habitat. These are of great potential effect on deer production and may result from multiple use management of these public lands, Grand Canyon National Park excepted. We believe that with careful planning deer values can be preserved or even improved and require no major concessions from presently competing users.

Efforts should continue to preserve thermal cover of woodland and improve forage allocation for deer in winter. The importance of winter range is evident from the loss rates there of fawns and first-bred females (Table 9).

Timber sale specifications should be carefully designed to retain and improve deer cover on the Kaibab Plateau. The importance of that summer range shows in the susceptibility of prime breeding does to losses there (Table 9). Allocation of forage in the forested habitat appears currently favorable on most parts and should be kept that way. Silviculture and timber management are potential threats to the cover essential for high survival of does and small fawns.

It is essential that we continue to collect data separated by age classes of all deer taken by hunters. Two studies of Kaibab deer mortality have shown this. A pooling of buck age groups is likely to obscure important changes in the buck population. It is also advisable to separate data of yearling from those of older does, although their age differences in survival/mortality rates were not as extreme as with the bucks.

Possibility of area differences in mortality should be further examined for both sexes, especially in National Forest vs. National Park and in mixed conifer vs. pine type. In addition to decisions on habitat just mentioned, these analyses would also benefit hunt management as applied to east and west herds, summer and winter range areas. Further inspection of radio deer mortality and losses should be done after data become available from the deer movements phase of this job.

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Appendices

Appendix 1. Criteria for determining cause of death.

1. Lion. A drag mark on the ground where the carcass was moved from the kill site to a feeding place is frequently associated with a lion kill. The carcass may be partially or completely covered with debris following feeding by the lion, or sometimes covered, uncovered, and re-covered several times between feedings. During this study all deaths classed as lion kills showed either the drag mark or debris covering or both. Characteristics of lion kills have been described by Hornocker (1970), Wade and Bowns (1982), and Shaw (1983).

2. Coyote implicated. Characteristics of coyote kills are not as unique as those of lions. Since the coyote is a scavenger as well as a killer, it is necessary to differentiate between an animal killed and then fed on from one which was merely fed on after dying from some other cause. Coyotes often dismember the deer carcass and remove major portions of it from the death site. On the Kaibab area we have noted the complete disappearance of carcasses of road killed deer within 24 hours, apparently as a result of feeding by coyotes. We have also observed deer carcasses that were only partly eaten and then never fed on again by coyotes. Two instances were reported elsewhere in which mule deer carcasses were almost completely consumed in less than two hours (Robinson 1952). One of these was a young deer killed by a single coyote. Nothing remained of the deer but scattered pieces of hide, a leg bone, and stomach contents. Robinson (1952) stated that game animals killed by coyotes may be eaten or carried away and cached with amazing speed, and that predation should be suspected if animals seemingly disappear and leave no trace. Such conditions make it difficult to determine the cause of death of a deer.

Coyote killed livestock have been described as having multiple bites to the head, throat, and neck, and sometimes the hind quarters (Wade and Bowns 1982?). Deer killed by coyotes have had bites to the throat, head, and neck (Ozoga and Harger 1966; White 1973; Truett 1979). In the present study we divided our judgments of coyote implicated deaths into the three following classes.

2. Coyote certain. There was little doubt that a deer was killed by coyotes when there was evidence of coyote feeding and tracks at the carcass plus signs of a chase and/or death in an open area. Chase was apparent when there was blood at locations other than the death site, and soil or vegetation disturbance or hoof dents or hair of deer on logs. Death in a stringer meadow or clearing within a forested area reinforced this judgment, since a sick or weakened animal would presumably tend to avoid the opening and seek cover or bed down in a thicket.

3. Coyote probable. This classification was given to recent deaths which had abundant coyote activity sign at the death site but could not be termed coyote certain because we could not tell if a chase and struggle had occurred or not. The conclusive marks sometimes failed to register or were not apparent in a continuously wooded area or an extensive sagebrush savannah type.

4. Unknown, coyote possible. The least certain assignment of coyotes as the death cause occurred when six to 10 days elapsed before we examined the carcass. There was evidence of coyote feeding activity as in #3 but more time and possibility of scavenging.

5. Unknown, no clues. For this class there was no evidence of death cause. Death occurred from 10 days to six months before the remains were found, if any. In some cases only the radio collar was found. There was no evidence either to implicate or rule out coyotes.

6. Unknown, poor condition. In these cases evidence of predator or scavenger (coyote) activity was present, but there was also evidence of predisposing factors such as extreme age or severely diminished bone marrow quality (Cheatum 1949).

7. Unknown, not predators. With some carcasses there was no evidence of predator or scavenger activity nor any predisposing conditions. Two of these carcasses were almost completely consumed by maggots with the hide nearly all intact over the skeleton. In another case the deer had simply crawled into a thicket and died untouched by predator or scavenger.

8. Legal harvest. These were antlered deer legally shot and retrieved during the hunting seasons.

9. Hunt season cripple and/or illegal. Antlerless deer shot during the buck only hunting seasons were clearly killed illegally. Legal status of bucks shot and not retrieved was a moot question, depending possibly on intent, perception, retrieval effort, and luck of the shooters.

10. Illegal non-hunt season. This refers to animals illegally shot at times other than the prescribed hunting season (poached).

11. Accident. This category was reserved for miscellaneous mishaps. It applied only to one adult female which impaled herself on a tree branch and punctured a lung.

Appendix 2. Clover traps.

Deer capture and collaring efforts began with a modification of the Clover trap 37 inches wide by 40 inches high by 66 inches long (94 cm x 102 cm x 168 cm) (Clover 1956). Side, top, end, and gate panels were of 4 inch by 4 inch (10 cm x 10 cm) mesh nylon net. Baits were leafy alfalfa hay, fermented apple mash, and mistletoe (*Phoradendron juniperinum*).

There were 23 Clover trap sites on west, east, and north winter ranges. To avoid costs of fence building the choice of sites was restricted to cattle corrals and water collectors, about 100 ft. by 100 ft. each, where fences already existed. Fence was essential to protect the baits and traps from cattle which occupy winter deer habitat. Due to mud and travel difficulties there were usually not more than six traps set per night, December 1977 to February 1978, and most of the effort was on the west side. The Clover trap technique was abandoned after the more successful method of the helicopter drive net became available (Beasom et al. 1980).

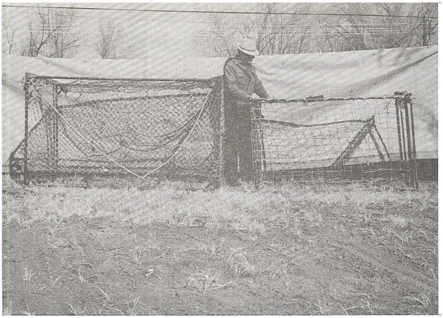

Fig. A. Collapsible panel net traps used in Utah (left) and on Kaibab area (right).

We believe that our low rate of capture success (3 deer in 300 trap nights) with the Clover traps was due their small size. Tracks and consumption of baits scattered outside the traps indicated that the deer were attracted, even when snow cover was sparse or absent and native forage was available. Deer were simply reluctant to enter the traps. This was confirmed by direct observation in one case. A doe fed for 15 minutes on sparse remnants of hay and apple mash just outside the trap. She repeatedly started to enter and then withdrew from the trap in which hay, apple mash, and mistletoe were abundant. We were informed of and also observed high rates of trap success on nearby deer management units in Utah. The traps used by the Utah Division of Wildlife Resources had denser mesh (2 by 2 inch, 5 cm by 5 cm) net panels and were 9 1/2 inches (24 cm) higher, 2 inches (5 cm) wider, and 17 inches (43 cm) longer than ours (Fig. A).

A fourth deer was trapped temporarily but escaped without being tagged or collared. Exit was through the 6 inch (15 cm) high opening at the bottom edge of the side panels, designed to minimize damage by rabbits chewing on the netting. Rabbits were a serious problem with bait consumption as well as net damage.

There were advantages and disadvantages to each deer capture method we used. When effective the Clover traps would avoid the administrative difficulties and cost of the drive net, which requires assembling crews of 30 people, helicopter charter, and scheduling to suit the weather. More important, the Clover trap could minimize bias in sampling a large deer population because capture sites could be dispersed more freely than with the drive net.

Appendix 3. Drive net.

Beginning March 1978 the drive net became the primary capture method. A helicopter was used to haze deer into a vertically suspended net of #96 nylon cord dyed brown and woven into 8 inch (20 cm) square mesh, which is stretched across the deer's anticipated flight path. The net, 500 yards (457 m) long and 8 feet (2.4 m) high, has 30 each 50 foot (15 m) panels fastened end to end. This union of panels is tied fast to solid objects only at its two free ends, and is supported by inverted V-frame props of unattached light weight poles at necessary intervals along its entire length. The net, which falls from its props when hit by a deer, is manned at intervals of 20 to 30 yards (18 to 27 m) by concealed crews who immediately restrain and collar the deer as they become entangled.

Capture sites were pre-scouted for deer tracks. Net sites were selected within the central 2/3 of what appeared to be an area of continuous deer use. The objective was to net the deer before they were driven out to an area that they normally did not use and was possibly not familiar to them. This facilitated the hazing. Rocky areas were avoided for the net site.

The helicopter hazing technique is a gentle one which allows the animals to move at their chosen speed until within 75 yards (69 m) of the net. The procedure was successful during December-March in pinyon-juniper woodland and savannah types. It is not suitable for tall coniferous forest types because the helicopter must fly within 50 feet (15 m) of the ground much of the time.

There were captures thus: 7 bucks, 66 does, 18 male and 14 female fawns including 104 individual deer (one doe was taken twice) at six east side and five west side sites during four separate drive net seasons. Success rates among seasons ranged from less than 1 to 4.2 deer/hour of helicopter searching and hazing, exclusive of flight time between base camps and capture areas. Deer were hazed into the net from distances as great as 2 1/2 miles (4 km). In one instance a herd of 18-20 animals was found 2 1/4 to 2 1/2 miles (3.6 to 4 km) from the net. By patient maneuvering of the helicopter 12 of the group were delivered into the net. Seven were caught on the initial thrust and two more were promptly taken as singles on short re-drives.

It is important not to excite the deer into headlong flight until they are almost within sight of the net. Allowing them to move more slowly most of the time helps the group stay together and promotes multiple captures.

Adjacent topography is important in selection of a net site. The deer we encountered seemed to favor running along ridge tops primarily, and along canyon slopes secondarily. The deer could also be driven across minor canyons and ravines. However, they were reluctant to travel along canyon bottoms and to cross treeless areas. When a ridge or flat area terminated in a steep slope or precipitous edge, the deer tended to run about 20 feet (6 m) from and parallel to the drop-off much of the time. No deer were killed in the drive net operations. Injuries were no more than skin abrasions and hair loss. Under the conditions of this study the helicopter drive net technique offered the obvious advantage of effective capture, which the available Clover traps did not.

Appendix 4. Rocket/cannon net.

There were 15 deer taken by rocket net and six by cannon net and released alive with radio collars on summer range, where neither the drive net nor the Clover trap method was attempted. The propelled net, 11 yards by 15 yards (10 m by 14 m), was of nylon cord tied into 4-inch (10 cm) square mesh. It was carried by four rockets attached equidistant along the leading edge and launched from supports on steel fence posts from points 4 1/4 feet (130 cm) above ground. The two rockets at outer sides of the net were aimed level and the inside rockets, at 5 degrees above horizontal. Charges were ignited by a 12 volt motorcycle battery.

Rocket and cannon netting efforts were confined to four sites. These were livestock corrals containing salt impregnated earth and free block salt. Two of the corrals contained water and the other two were within 200 yards (183 m) of livestock water in dirt tanks (earthen reservoirs). The block salt was placed to attract deer directly into the path of the net. The corrals were closed to exclude livestock during trapping hours.

A trip line of monofilament nylon was stretched around the salt at 12 inches (30 cm) above the ground, with the line forming an equilateral triangle. Base of the triangle was less than or equal to 10 feet (3 m) ahead of the leading edge of the furled net and parallel to it. The opposite point of the triangle extended backward over the furled net and anchored to a standard wall type electrical switch mounted on a heavy piece of wood. Early attempts were made with the trip line extended to 15-20 feet (4.6-6 m) ahead of the furled net, but the first six discharges netted only three deer. Three

deer apparently outran the flying net when the trip line was thus excessively extended.

With the trip line laid out in the shape of the small triangle, less than or equal to 10 feet (3 m) on a side, 21 firings captured 18 deer. One of the three unsuccessful firings may have been triggered by a deer which escaped despite proper casting of the net. In another case the net did not cast properly and whatever triggered it escaped. The third unsuccessful firing was triggered by an owl, identified by the plumage which it left.

In early July 1979 daytime sets were made. The net was intended to be fired by hand from a blind but no deer came in. Salt use within the livestock exclosure seemed to occur primarily at night. All further rocket and cannon net attempts were made during sunset to sunrise of June-August periods.

On 12 July 1979 a hand fired night set was made under a full moon phase. Between sunset and moonrise (one hour) several deer entered the fenced area which contained water and green grasses and forbs as well as salt. As moonlight began to increase all but one deer left the exclosure. The remaining individual stayed at the salt block long enough to be spotted with 10 x 50 field glasses and captured. Subsequently all sets were made with the automatic trip line described above.

Full nighttime darkness facilitated this technique. Of the 21 deer captured by the automatically fired net 20 were taken either during the darker moon phases; or before the moon came up or after it went down during the 3/4 to full moon phases.

Use of salt by deer and consequent effectiveness of salt as bait seemed to be greater during dry than during wet periods. More net firings and deer captures seemed to occur prior to the summer rainy season or when there were prolonged intervals between summer rains. Further study would be needed to explain the associated phenomena of darkness, dryness, and salt consumption by does on summer range.

At one point in the study solid rocket fuel became unavailable and it was necessary to use cannon type projectiles to carry the net. This method used a black powder charge ignited by electric blasting matches and delivered a recoil thrust to the launchers. To reinforce them two additional steel fence posts were bolted to each of the single post rocket launchers thus forming four tripods. The three legs of each were then staked to the ground with 12-inch (30 cm) steel pins. At each firing of the cannons all four tripods were overturned and much of the wiring ripped out, but the net flew satisfactorily. The cannon propelled net was as effective as the rocket net when the short trip line was used, although clumsy and time consuming to reset.

During the entire study 3 bucks and 20 does were captured in 67 nights of rocket and cannon net efforts. All but one were single captures. A buck and doe were captured together and the buck strangled before he could be released. This was the only capture mortality of the study. All animals taken by rocket and cannon nets were one year old or older. There was never more than one firing on a single night. Night wandering humans were not expected in the vicinities of these net sites. However, this method is a

potentially lethal hazard for people. Due to site restrictions it is of limited usefulness for the purpose of obtaining a dispersed sample of a large deer population. Bias against bucks was obvious.

Appendix 5. Radio collars.

The 88 radio transmitters used in this study were all purchased from Telonics, Inc. of Mesa, Arizona. All units emitted a pulsed signal operating in the frequency range of 148.000 to 148.999 mHz. Pulse rate ranged from about 750 to 860 ms. All units were also equipped with mortality sensing circuitry which caused the transmitter to approximately double its pulse rate when the animal carrying it became motionless. The time delay to initiate the fast pulse varied during the study period but was normally about 4 hours.

These units have operated well within design specifications and have averaged 2.9 years of operating life. A summary of that performance is given below.

Transmitter performance summary.

	No. Units	Days Use Min.	Days Use Max.	Average
Transmitters recovered operating				
1 installation	17	14	1580	798.6
2 installations	5	653	1613	1055.0
All transmitters				856.9
Transmitters not recovered and still operating				
1 installation	11	1361	2394	1539.2
2 installations	4	1997	2120	1664.8
3 installations	3	1704	2115	1900.7
All transmitters				1627.4
Transmitters not recovered and signal lost				
1 installation	35	56	2072	1164.2
2 installations	9	393	2064	1316.0
3 installations	1	698	698	698.0
All transmitters				1184.2
Transmitters recovered and not operating				
1 installation	2	1062	1912	1487.0
2 installations	1	947	947	947.0
All transmitters				1307.0

The radio collars were a Butyl-Dacron combination webbing 2 inches (5 cm) wide and 3/16 inch (5 mm) thick. Females had collars from 13 1/2 inches (34 cm) to 19 inches (48 cm). Does with the smallest collars showed no ill effects although the fit was snug and there was no room for air circulation under the collar. The only problem noted with the larger sizes on does was hair loss caused by slippage of the collars. Does had an average neck circumference of 13 inches (33 cm) at one inch (2.5 cm) below the angle of the jaw.

Early in the study several male fawns were equipped with collars that were too small for growth and neck swelling during the rut. Two bucks died at ages 26 and 29 months as a result of tracheas that collapsed under collars that were 15 and 16 inches (38 and 41 cm) in circumference. One buck with an 18 inch (46 cm) collar was killed by a hunter at age 4 1/3 years. The collar then was cutting into the neck hide which discharged purulence. Neck swelling for the rut was just beginning and probably would have caused death of the deer had it not been harvested.

Male fawns captured later in the study were equipped with 23 inch (58 cm) collars that had soft foam liners, one inch thick (2.5 cm), glued to their inside surface to prevent them from slipping over the head of a young deer. The foam deteriorates with age. None of the foam lined collars (23 inches, 58 cm circumference) was lost. Two of these individuals were harvested at ages 3 1/4 and 4 1/4 years at start of rut and their collars had become snug to tight fitting.

Some compression of neck tissue can be tolerated, perhaps as much as that resulting from 5 inches (13 cm) constriction in the circumference. Future operations should use 24 inch (61 cm) collars as a minimum size for males, with appropriate foam lining for male fawns. These recommendations are based on results of measurements at one inch (2.5 cm) below the angle of the jaw on buck carcasses in the third week of November 1983. Average circumferences were 21 inches (53 cm) for bucks age 2 1/3 years, 25 inches (64 cm) for bucks age 3-5 years, and 23 inches (58 cm) for bucks age 6-8 years. However, about 10 percent of the individuals age 3-8 years measured 28 to 29 inches (71 to 74 cm).

In addition to the radio collared animals mentioned above there were captured and released 14 individuals marked only with ear tags and/or colored collars without radios. They were seven does age greater than 12 months, and five male and two female fawns age six to nine months. These non-radio marked animals were excluded from all mortality calculations.

Appendix 6. Rabbit counts.

Standard procedures for the rabbit counts were as follows: Observers per vehicle, one; vehicle, pickup truck with headlights on high beam; speed less than or equal to 15 mph (24 kph); start time of first run, 30 minutes after full nighttime darkness, ca. sunset plus 60 minutes; start time of second run, at end of first run; runs per route per night, not more than two; sighting distance, count all rabbits visible on road and shoulder; species tally, separate jackrabbits and cottontails; route description, see annual Job Description in Department files.

During the first year with the rabbit counts it was determined that repeat runs of a route in the same night merely duplicated results of the first run. Only the results of the first run of each night were used in the following tabulation for 1979, and only one run per night was made during the later summers.

Counts were highly variable among the five nightly runs within each year on each route. We therefore report the high nightly count as well as the mean of the five counts for each route each year. The former indicates the minimum number of rabbits present along the route at a given date. (Table A).

Table A. Rabbits per road mile.

WEST SIDE

	Jack Rabbit			Cottontail		
	Mean	High[a]	Coeff. of Var	Mean	High[a]	Coeff. of Var
1979	2.55	3.94	35.09	.19	.25	39.41
1980	.91	1.37	34.07	.04	.07	37.27
1981	.92	1.60	45.71	.06	.11	71.26
1982	.50	.65	27.45	.05	.11	86.07

EAST SIDE

	Jack Rabbit			Cottontail		
	Mean	High[a]	Coeff. of Var	Mean	High[a]	Coeff. of Var
1979	.11	.14	26.15	.07	.10	20.33
1980	.17	.30	48.99	.02	.03	91.28
1981	.25	.37	43.37	.02	.03	91.28
1982	.24	.31	20.20	.05	.10	55.90

The indices show that the west side jackrabbit population was high in 1979 and the east side population was not (Table A). For the remainder of the study, through 1982 and perhaps later, jackrabbit population levels were low on both west and east sides. Cottontail levels were low throughout the study on both sides.

Appendix 7. <u>Comparison of Study Methods</u>.

The method of estimating survival/mortality based on changes in abundance of harvested age classes of deer was economical because it used data collected largely for other purposes not directly charged to the study. The information was borrowed from the routine annual game management inventories of herd size, harvested numbers, physical condition, and field classification counts. Lab service to examine the deer teeth was the principal direct cost other than data analysis.

The change in age ratios technique requires that the population size be either stable or else changing at a steady rate over a period of several years (Barlow and McCulloch 1984). These conditions possibly may not occur whenever an estimate of mortality is desired. It is not feasible to kill a large enough sample of deer to make a reliable and accurate estimate for a brief period such as one or two years; nor to make seasonal estimates of mortality which are in some ways more informative than annual ones. This method also was not usable for bucks younger than 3.4 years due to biases that result from abrupt phenological changes in buck behavior, variable hunt season dates, and hunter selection of bucks. The method is impossible for does during buck-only hunting; and of questionable interpretation when hunts are designed to create geographic differences within the mature buck population aged 3.4 years and older.

Analysis of changes in age ratios could not be used to estimate mortality by cause except for two, the reported harvest by licensed hunters and the lion kill rate. The opportunity to estimate the latter causes was unusual and was based on assumptions derived from lion kill rates which followed soon after the period for which deer mortality was actually estimated. Unlike the annual deer management inventories, frequent assessments of the Kaibab lion population are not feasible.

The chief advantage of the radio-telemetry method was its potential to determine mortality rates by causes. Another advantage was the ability to detect phenological differences which are clues to habitat quality as well as direct causes of mortality. Also, with some additional effort, useful information accrued from this technique which significantly expands the knowledge of deer migration dates, routes, and destinations.

Expense was a major disadvantage of the technique of radio monitoring the life or death status of deer on the Kaibab area. Aside from costs of capture nets and radios this method required large investments of personnel and machinery not chargeable to other objectives. Used for on-site field work only, March 1978 to June 1983, were 60 hours of helicopter flight time, 1500 hours of fixed wing aircraft flights, 484 person days for deer capture, and 548 days for monitoring and dead deer search and examination. This account excludes efforts during two months at the start of the study when Clover-type traps were tried, as described above in this Appendix.

The effective capture techniques may have biased the radio deer sample. Both the helicopter drive net method and the rocket and cannon net required special and fixed site conditions, and may have avoided certain groups of this migratory deer population. We suspect that it is not homogeneouslyl exposed to mortality hazards. There are apparent site differences in deer group sex and age composition and physical vigor, and in forage sources and cover conditions, and in density and distribution of predators. Broad and random selection of individuals was desirable for the radio-collared sample, but may not have occurred with the clustered sampling procedures actually used to capture deer.

Another disadvantage was radio failure, the rate of which could not be known. This created a margin of error in the calculated mortality rates of the radio sample group of deer.

Quality of the data and resultant estimates of mortality are budget dependent with the radio-telemetry method. About 23 per cent of the mortality rate of does older than 12 months (3.3%/14.2% confirmed) could not be assigned to any confirmed or probable cause. Much of this loss of information was due to delay between deaths of the deer and discovery and examination of the remains. We estimate that a significant reduction of that loss of data would require a doubling of the equipment and personnel assigned to the monitoring flights.

The radio-telemetry method has more advantages except for cost, but that factor will prohibit future use of it on the Kaibab area. The change in age ratios technique based on tooth collection should be used whenever conditions permit, but that may be seldom. The radio method seems attractive for evaluating mortality of a small deer population on a small area where capture and monitoring needs would be less extensive than on the Kaibab area.

Appendix 8. Unexplained Silence in Relation to Poaching

Survey crews encountered radio-collared and non-radio does at the rate of 1:88 and poachers presumably had the same chance of seeing marked among unmarked deer. If poachers took does as encountered, they should have killed 1,496 does in the process of silencing the 17 radios (Table 13). That amount of poaching activity seemingly would have been noticeable. Further, if poachers for some reason selected marked deer, then even more poaching effort and activity was necessary to silence those radios.

A different hypothesis would grant poachers and licensed, successful doe hunters equal hunting skill and luck and net effectiveness in taking does. Thus, as calculated per the method of mean daily survival, poachers would have spent 938 days per year to inflict the observed rate of attrition represented by unexplained radio silence. This also is a seemingly conspicuous amount of poaching activity. Skilled and careful poachers could, of course, invalidate the above assumptions.

As judged by deer survey data, the likelihood of poachers silencing a buck radio was extremely small. Survey crews did not see a radio-collared buck among a total of 6,126 deer recorded, although unexplained silent radios did occur among the bucks (Table 13).

As previously stated, we believe that radio failure caused much of the unexplained silence. Of the radios which went silent, 13/23 did so before expiration of the manufacturer's warranty of 2-1/2 years. The two proven failures functioned for only 4 and 9 months.